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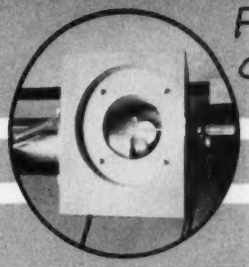


research trends

CORNELL AERONAUTICAL LABORATORY, INC., BUFFALO 21, NEW YORK

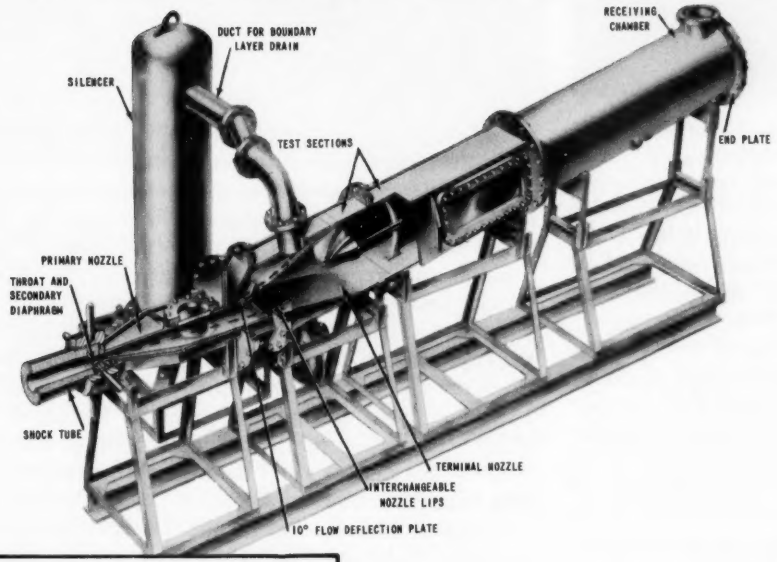


FIG. 1 — One of CAL's 11 x 15-inch hypersonic shock tunnels.

A Problem in Measurement

by WILLIAM E. SMITH

Learning What Takes Place in Shock Tunnels During Short and Severe Tests

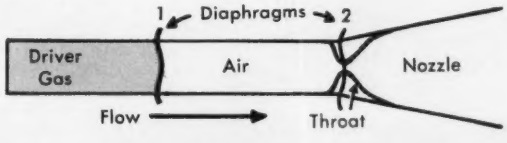
Intercontinental ballistic missiles, hypersonic gliders, skip-re-entry vehicles, and manned satellites and space rockets all share one difficulty: re-entering the earth's dense atmosphere at tens of thousands of miles an hour.

Whatever other effects hypersonic speed regimes are having, one fact is sure — they are outstripping in many respects the testing facilities of conventional wind tunnels. New problems often demand new tools for their solution. Thus the shock tube, virtually unknown a decade ago, has today become one of the most important research tools in universities and in governmental and industrial laboratories around the world. Predetermined conditions of high-temperature, high-pressure, and high-velocity flows of controlled purity can conveniently be produced in shock tubes to a degree unequalled in any other laboratory environment. In addition to these capabilities, three other attributes contribute to the shock tube's popularity as a tool: economy, versatility, and controllability.

If the air in a shock tube is rapidly compressed to extreme conditions, then expanded through supersonic nozzles, a model immersed in the flow will experience

What is a Shock Tube?

A shock tube is commonly a straight tube containing the gas (air) to be studied and the driver gas (helium or hydrogen) to do the work of shock compression. Both gases might be at room temperature initially. When the driver gas is at the chosen high pressure, diaphragm No. 1 breaks and the driver gas acts like a light, energetic piston on the air. If a nozzle is attached, a film-like diaphragm permits the nozzle to be evacuated beforehand, insuring minimum impedance to the passage of the air during the test. The steady flow duration available for testing at any station in the nozzle can be increased tenfold by placing a constricting throat as indicated



so that the air bleeds into the nozzle at a reduced rate. This modification is called the "tailored-interface" shock tunnel. For a more complete discussion, see "Wings of Icarus" by Abraham Hertzberg, *Research Trends*, Summer, 1955.

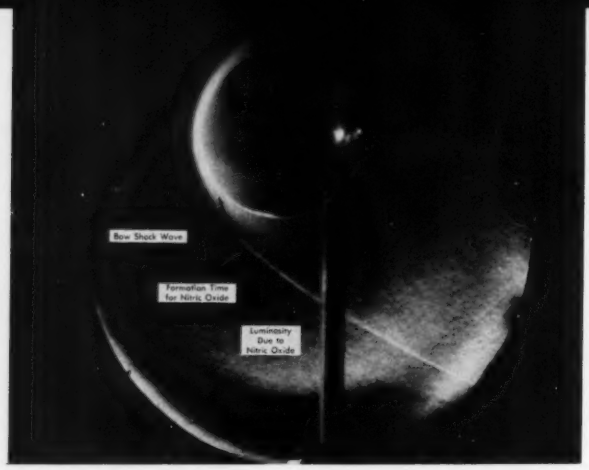


FIG. 2 — Schlieren photograph of hypersonic flow of 10,000°F air around a 3.5 inch glass sphere.

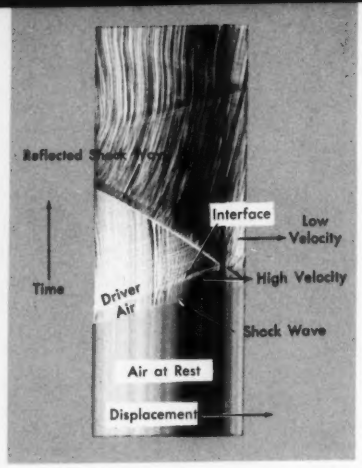


FIG. 3 — Continuous strip film here shows air accelerated by a Mach 3.5 shock wave toward the partially constricted right end of the shock tube. The constriction reflects a shock wave with the strength needed to bring the air to low velocity, as dictated by the boundary conditions.

conditions similar to those which will be encountered by, say, an intercontinental ballistic missile in free flight. Figure 1 shows the nozzle modification developed by Cornell Aeronautical Laboratory to convert the simple shock tube to a hypersonic shock tunnel.

Such shock tunnels, however, are not without limitations, chief of which is the short duration of steady flow of air over the models. In a typical CAL installation, a column of air initially 14-foot-long supplies steady flow to the test section of a tailored-interface shock tunnel for about nine milliseconds at Mach 6, and for four milliseconds at Mach 10. The problem facing the researcher, then, is how to extract the desired information about the air and its influence on test models within the short duration and under the severe conditions of the experiment.

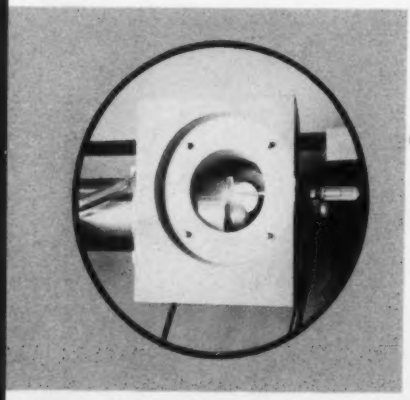
Flow Measurement

Of critical interest to the hypersonic researcher is the physical behavior of the gases within the shock tunnel. To enable him to "see" the flow of gases, he uses several common systems of optical measurement: shadowgraph, schlieren, interferometer, and the spectrograph. At CAL, schlieren optics have been applied to short-duration events with good results.

In schlieren photographs of a gas, density gradients in the gas show up as changes in light intensity or in color, thus identifying shock waves, regions of compression and expansion, and wakes (Fig. 2). A continuous light source can be used to illuminate film in a high-speed framing camera, such as the commercially available Fastax, or in a continuous strip film camera (Fig. 3). The latter is particularly useful in observing one-dimensional phenomena, because the strip film yields a time-vs.-displacement record. In the strip-film method, the camera looks through a slit parallel to the tube axis, as the film moves perpendicularly past the slit.

Another schlieren method uses a short-duration light source to illuminate a stationary photographic plate. A high-voltage spark in a three-electrode open gap configuration (inset photo, p. 2) provides a light of sufficient intensity for most purposes. Its duration is about a tenth of a microsecond. Fig. 4 illustrates dramatically the "stopping" ability of this photographic system. In the upper picture, a shock wave moving into still air at 9000 feet per second is frozen by the fast light source. The gray region behind the thin shock wave in the lower picture represents the gradual change in density as the highly excited air molecules "relax" into thermodynamic equilibrium. The relaxation time is thus measurable with a sufficiently fast spark. The relaxation zone in Fig. 4 measures about a quarter-inch, 20 times the distance the shock wave would travel during the time the spark is illuminating it. (The relaxation phenomenon is discussed at length in "A New Air for Engineers" by J. G. Logan, Jr., **Research Trends,** Spring, 1957.)

A sequence of several individual high-speed light sources of the type just described can be used to illuminate a strip of moving film. Consider, for example, a series of spark gaps with optical condensing lenses between each pair to collect the light from one and to bring it to focus at the next. One has what amounts to a single source of light in space, but several sources in time (Fig. 5). In terms of photographic quality, this method is an improvement over ordinary framing camera methods. Multiple spark techniques are not new. However, repeated sparking of one set of electrodes is limited by the natural frequency of the electrical circuit. The source-lens-source combination provides the re-



THE COVER

For schlieren photography, this light gun illuminates the gas flow for one-tenth of a microsecond. The one-inch diameter brass rod and two-inch brass tube are separated by a barium titanate ceramic tube in what amounts to a transmission line. A signal derived from the shock compression of the air in a shock tube triggers the spark. When the air gap between the 3000-volt trigger electrode and the 10,000-volt brass rod breaks down, a discharge wave travels the seven-inch length of the transmission line from the gap to the opposite end, which is for all practical purposes open. The discharge wave reflects from the open end of the line and returns to the gap with opposite sign, thus reducing the potential of the line to near zero and quenching the spark. Subsequent discharges are thus prevented.

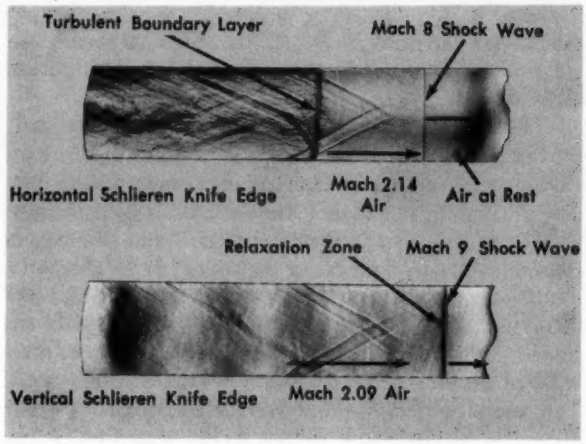


FIG. 4 — Typical schlieren photographs of strong shock waves in air.

searcher absolute control of the frequency of his observations during a single rapid event.

Pressure Measurement

Of interest in shock tunnel research is the development of the shock wave and the flow behind it. To trace this development in the straight shock tube, the engineer commonly relies on the measurement of static pressure. Flush-mounted transducers are placed at several stations in the low-pressure section and, if a combustible gaseous mixture is used, at several stations in the high-pressure section to monitor the driver pressure.

The sensitive element of the transducer must be sufficiently small to locate accurately the thin shock wave which passes over it, must be fast enough to respond faithfully to the step-function input, and must have a satisfactorily low frequency response to provide a meaningful record long after the arrival of the driver gases. The requirements are stringent and the loads applied through the gases and through the tube walls are severe in CAL's shock tubes.

Another difficult problem is to measure a small but unsteady pressure, such as that at the wall of the shock tunnel test section. The actual pressure there is initially a few millimeters of mercury. The shock wave initiating the so-called starting period produces a pressure of about 1/20 psi. Then the passage of other waves raises the pressure abruptly to about ten times that value, where it remains more or less constant. Suitable gages for these applications are now becoming commercially available.

Force Measurement

The conventional force balance system used in steady flow wind tunnels is essentially a system which, under the influence of such applied aerodynamic forces as lift and drag, achieves a steady-state displacement. Because the shock tunnel testing time is on the order of a millisecond and, more important, because the aerodynamic forces will vary during the test, the force balance must respond to high-frequency transients. The force balance system in a shock tunnel should allow the model to move within its support with negligible restraint. In other words the period of oscillation for the model and support system should be large in comparison with the testing time.

A three-component balance system has been designed to be contained in a small conical model (Fig. 6). The model, the three accelerometers, and the two springs weigh about eight ounces. The resulting natural frequency is about 10 cycles per second, small enough to insure that, under constant applied force, the accelerations vary only about one per cent during four milliseconds. With suitable noise filters, the balance system shown can provide drag, lift, and pitching moment data in a shock tunnel.

Heat Transfer Measurement

Heat transfer data in the shock tube or shock tunnel environment can be collected using resistance thermometers of a special but simple design. When a metallic film of about one millionth of an inch thickness is bonded to a dielectric surface (pyrex or quartz are commonly used), the film takes on the surface temperature with a lag which is small compared to the testing time. The easily detected changes in electrical resistance of the film are a measure of its temperature history during a run and, therefore, of the heat transfer rate at the small gage area. The surface temperature may increase only one degree during a run, but the corresponding heat transfer rate may be hundreds of Btu's per square foot per second.

Furthermore, in this environment, the heat penetrates less than one thousandth of an inch into the surface. Therefore, within the body, wall or model, the

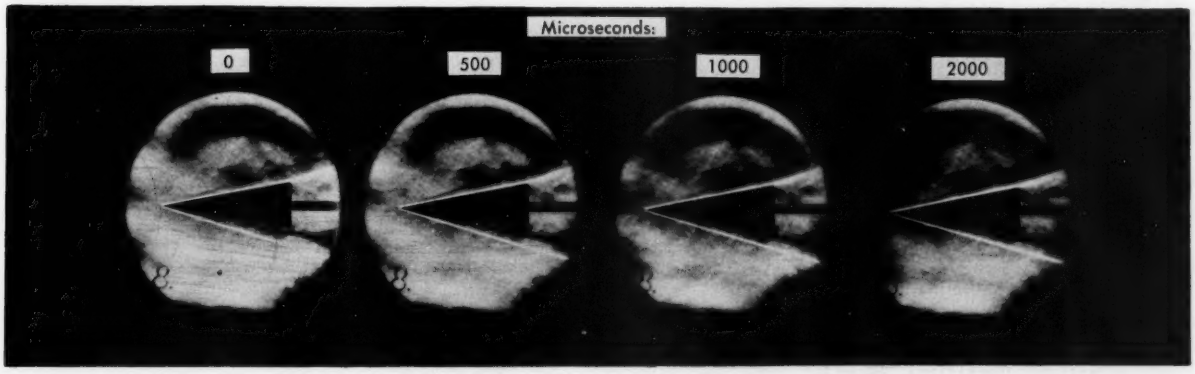


FIG. 5 — Schlieren photographs showing Mach 8.5 flow developing on a 20° wedge in a CAL hypersonic shock tunnel. Each frame is exposed for 10^{-7} seconds.

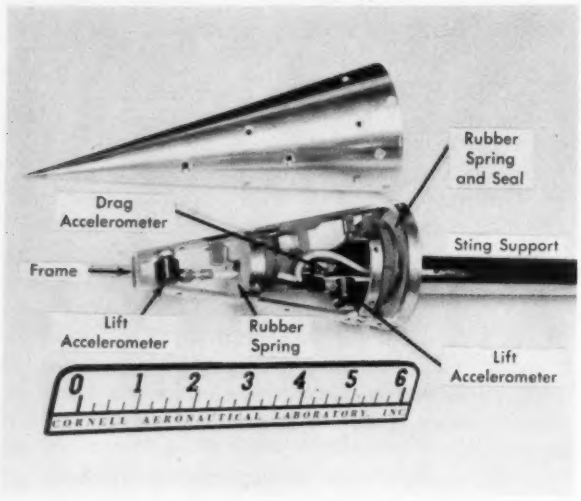


FIG. 6 — A 20° conical model with internal balance system designed for the hypersonic shock tunnel. The three accelerometers are rigidly attached to the cone. The system is suspended from the sting by two donut-shaped rubber springs and is virtually unrestrained during the test.

heat flux normal to the surface must be orders of magnitude greater than the heat flux parallel to the surface (the latter being restricted to a small area, one of whose dimensions is the one-thousandth-inch penetration). In other words, unlike the case for models in steady-flow tunnels and in free flight, the heat flux is a one-dimensional phenomenon in the shock tube/tunnel. This lends a certain "purity," i.e., separation of parameters and control of variables, to such experiments. It has become as common and simple to measure heat transfer to models in shock tunnels as it is to measure pressures in wind tunnels.

The resistance thermometers can precisely signal the passage of the shock wave, and are thus used to measure the all-important shock velocity in the constant-area section of the shock tube, as well as the rate of heat transfer to various bodies immersed in the relatively dense flow of air and the rate of heat transfer to the tube walls after passage of the shock. Such gages also facilitate study of flow oscillations which may occur on a model in a shock tunnel test section, thus identifying the unsteady starting period and the ensuing steady test period.

Radiative Measurement

At the temperatures of hypersonic speeds air is excited to new and interesting states. In a shock tube one can excite air and other gases uniformly and rapidly to more than 20,000°F and can study spectroscopically their radiative properties. An intimidating array of instrumentation must attend a typical experiment to measure, say, the absorption coefficient of air at 7400°F and at four times atmospheric density.

A seventeen-foot, closed-end shock tube is chrome-plated inside for spectral purity. A scribed, stainless steel diaphragm separating the light driver gas from the air to be studied is fractured at the appropriate instant to initiate the run. Ionization-sensitive gaps along the tube detect the passage of the shock wave to permit calculation of flow properties behind it and to initiate other events.

The shock-heated air is brought to rest momentarily by the closed end of the tube where some 100 microseconds are available to examine it through quartz windows.* During less than 10 microseconds of this interval, and at a time selected with a certainty of ± 2 microseconds, a xenon flash lamp, reproducible in character, illuminates the air sample with a spectrum of visible and ultraviolet light. A quartz spectrograph records the transmitted illumination as well as the emission spectrum of the air itself and, separately, the emission alone. The useful observation period is terminated by the arrival at the window of the driver gas and of impurities from the diaphragm. A rapid-closing shutter intercepts the light path before this extraneous emission occurs.

Suitable calibration procedures permit quantitative analysis of the air properties. For example, for the conditions mentioned above, air is opaque to ultraviolet radiation to an unexpected degree: over 97% of the incident energy at wave lengths shorter than 2600 Å is absorbed in one inch of this air.

Conclusions

Shock tube and shock tunnel measurements demand extremely rapid rise times, in addition to the sensitivity normally required in hypersonic nozzle testing at low densities. Whether measurements are to be made using optical systems, pressure or force transducers, or resistance thermometers, techniques have been developed and are being refined to satisfy the special requirements. While basic problems of measurement are thus being solved, the scope of shock tube research into problems of physics, aerodynamics, and chemistry is expanding rapidly. To keep abreast of this expansion we must continue to seek new and better methods of measurement.

*An alternative method for studying gaseous species in a shock tube is to compress and heat the gas sample in a closed-ended tube as above and, after a controlled dwell period of some microseconds, to quench the reaction. This is done by opening a diaphragm at the far end of the driver section which is connected to a large, evacuated tank. The ensuing gas motion expands the reactant, cooling it at a rate of millions of degrees per second. The products from this "chemical" shock tube can then be extracted and studied at leisure.

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Propellers - A Vanishing Race?

by JOHN P. ANDES

In an age when military aviation depends almost exclusively on jets, and when commercial jet transports like the 707 and the DC-8 are arriving on the scene, why do we not just pat the propeller on the back, thank it for a job well done, and bury it quietly? Several compelling facts offer the answer.

Propellers, simple airscrews which convert the engine's torque into axial force, have been historically associated with piston engines. The propeller manufacturer will be the first to admit that the piston engine is on the wane. He will be quick to point out, however, that great economic advantages in load-carrying capacity and shorter take-off and landing distances can be achieved by marrying a high-performance propeller to a gas-turbine engine. The problem, of course, is to develop the all-important, high-performance propeller.

Cornell Aeronautical Laboratory has tackled experimental propeller research for the past five years. Although the test program has not reached the point where complete answers are available, test equipment and methods have been developed for detailed study of high performance propellers and much data have been obtained which assist in optimum design.

"Johnson hasn't worked in months. He's our propeller expert."
—*(Reprinted from Aviation Age Magazine, May, 1954.)*

As modern high-performance aircraft demanded more powerful engines, the reciprocating engine rapidly grew too big and heavy and aircraft designers were forced to seek acceptable substitutes. As a result, the turbine gas generator was developed and with it came tremendous increases in engine power without prohibitive weight or size.

This new air-breathing engine delivers its power in the form of high-velocity gases. These gases may be used directly on a straight momentum reaction principle, or indirectly to drive a turbine, which in turn drives a propeller.

More Efficient Propellers Needed

Momentum equations show that the thrust delivered by a turbo-prop power plant is greater than that from a turbo-jet of equal weight. Therefore, in order to get the same thrust for the same duration, the fuel supply and gas generator of the turbo-jet must be increased (Fig. 1).

It becomes apparent, then, that the choice of a power plant for a given application depends in part on the weight comparison shown in the illustration above. The choice also depends on the performance of the propeller, as measured in terms of efficiency.

Unfortunately, propeller design and development in the last 10 years did not keep pace with the revolution in power plants. As a result, conventional propellers lacked efficiency at high airplane speeds, and could not absorb the large powers involved. So, the need was evident — if there were to be turbo-prop airplanes capable of carrying big payloads at high subsonic speeds, a more efficient propeller would have to be created.

The first step was to scrap the old design criterion for propellers and create a new one. It was no longer enough to keep a high lift-to-drag ratio on the propeller section by keeping the tip velocity of the propeller below the critical Mach number (that Mach number at which a rapid rise in drag takes place). Designers had learned that the rapid fall-off of propeller efficiency was directly related to the airplane's speed. As the speed increased, the advance ratio or relative wind angle became so large that the component of thrust in the forward direction became very small, even though the lift-to-drag ratio remained high. Thus, the concept of limiting top-speed was discarded in favor of optimizing the pitch or blade angle at the subsonic speed. Although this method looked good in analytical studies, a serious dearth of experimental data on thin propeller blade sections has prevented experimental verification.

CAL Develops Dynamometer

To supply the missing data, the Propeller Laboratory of the Wright Air Development Center in 1949 authorized Cornell Aeronautical Laboratory to design and develop a propeller dynamometer. This device was to measure the efficiency of model propeller blades in a wind tunnel capable of testing at high subsonic airplane speeds. To this end, the dynamometer measures the propeller's power input and thrust output.

In 1949, CAL began designing the dynamometer to a rigid set of specifications covering power requirements, rotational speeds of the shafts, accurate power and thrust instrumentation, and the overall size of a housing that includes a complicated set of gears and bearings. The dynamometer as it now stands has a 12-inch diam-

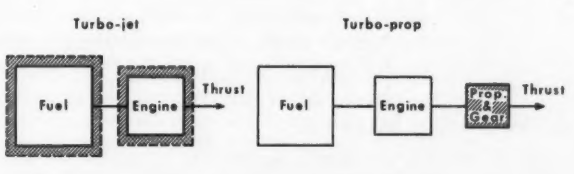

FIG. 1 — More fuel and a heavier engine are needed if turbo-jet thrust is to equal turbo-prop thrust. Shaded areas compare additional weight of fuel and engine in the turbo-jet and additional weight of propeller and gear in the turbo-prop power plant.

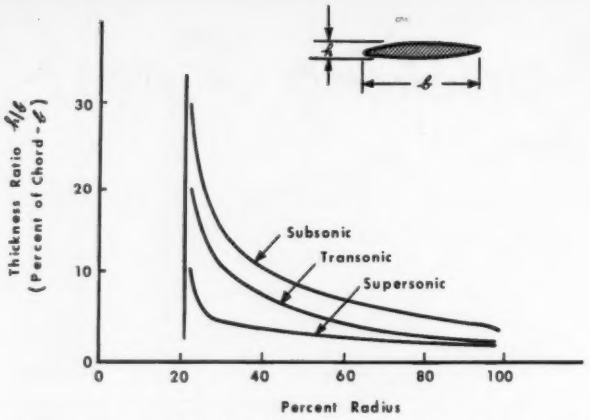

FIG. 2 — **Typical blade thickness ratio is shown for subsonic, transonic and supersonic propellers.**

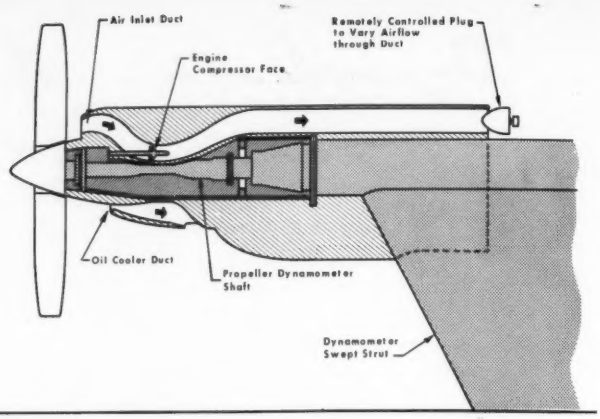

FIG. 3 — **CAL's propeller dynamometer has been used for experimental research on air induction models. A typical installation is shown above.**

eter nacelle mounted on a swept strut whose thickness is approximately 3% of the total length. Its two concentric shafts can be rotated individually or locked together. Each shaft can transmit 1000 hp up to a speed of 8000 rpm thus permitting measurement up to 1000 pounds of thrust.

Two 2600 hp synchronous motors (one for each shaft) supply power to the dynamometer through two Dynamatic couplings (which can transmit 1000 hp) for shaft speed control. These motors and couplings are mounted on a specially built platform outside the tunnel circuit. The power developed by this system is transmitted by suitable gearing and shafting through the wall of the tunnel up to the dynamometer or propeller shafts. Measurements of the thrust produced and the horsepower absorbed by a propeller configuration are made by cantilevered beams, instrumented with electrical strain gages and mounted to the shafting inside of the dynamometer nacelle.

The dynamometer tested its first propeller in late 1951, approximately 30 months after the design was initiated, and after about one million dollars had been spent on it.

Types of Propeller Blade Designs

Projecting the aerodynamic requirements of propellers for modern-day, long-range transports, we find that the propeller must operate over speeds ranging from low subsonic through the transonic regime. The wide variation in flight speeds requires the use of different propeller types, so that optimum efficiency may be obtained at the particular airplane design condition. These types of propellers can generally be grouped as supersonic, transonic and subsonic, the terms referring to the speed of the propeller blades. The supersonic propeller is primarily designed for flight speeds of Mach 0.90 to about Mach 1.0. Its exposed blade sections operate at supersonic speeds at all times in the design conditions. During off-design conditions, such as takeoff and climb, the inboard blade sections may be operated at speeds below Mach 1.0.

A transonic propeller is usually required for aircraft flying in the range of Mach 0.75 to 0.90. Blade section velocities of the transonic propellers may be above or below Mach 1, depending upon the flight condition. The useful range of flight speeds for the subsonic propeller extends from Mach 0.20 to Mach 0.65. This propeller has been termed subsonic because no section of the blade has to be operated appreciably above Mach 1.0, for any major flight condition.

Important physical differences among the three types of propellers are the diameter and thickness of their blades. The supersonic propeller blade has substantially thinner sections and a smaller overall diameter than the subsonic propeller, and the transonic propeller, as suggested by its name, falls somewhere between the two.

Data Needed for Design Purposes

Propeller companies and the Propeller Laboratory of WADC have studied the performance of turbo-prop airplanes, using one or all of the three types of propellers. Results generally indicate that turbo-prop aircraft are superior to turbo-jet for a 650 mph long-range airplane, if the ratio of power plant weight (which includes fuel) to airplane gross weight can be kept small. The increased areodynamic efficiency obtained from the propeller lowers the fuel weight necessary for a specific mission and allows a greater payload to be carried. The problem, then, confronting the propeller industry was to obtain, on all types of propellers, data which could be used for design purposes.

To provide these data, several families of model propeller blades were designed and fabricated. These blades have no full-scale counterpart and were designed only to study different physical parameters affecting aerodynamic performance of the propeller, such as the inboard blade section thickness, planform shape and blade pitch distribution. Fig. 2 shows typical propeller blade thickness ratios for subsonic, transonic, and supersonic propellers.

Blade Stress and Aerodynamic Research

Both propeller blade stress investigations and aerodynamic investigations have been performed in CAL's wind tunnel. Blade stress investigations are usually conducted to obtain qualitative data on the stall flutter boundaries of these model propeller blades to determine the safe operating ranges for aerodynamic testing. Electrical strain gages are bonded to the blades and the combination of steady and vibratory stresses is monitored over the range of Mach numbers and

rotational speeds which are anticipated for aerodynamic testing. The actual range of Mach numbers and rotational speeds depends, of course, on the type of blade being investigated. Since these tests are usually of a qualitative nature, only high stress values are recorded.

After the safe operating ranges of forward and rotational speeds are established, the blades must be stripped of the strain gages before aerodynamic investigations begin. Since the supersonic blades are so thin, the thickness added by the strain gages, just over a hundredth of an inch, could have a detrimental effect on performance.

Aerodynamic investigations have been conducted over forward speed Mach number ranges of 0.10 to 0.90, rotational speeds up to 7500 rpm and blade angles from $-5°$ to $+60°$. Up to 2000 hp is available for these tests. Thrust production and power absorption qualities are measured over an advance ratio and blade angle range for constant values of Mach number. The advance ratio range has been covered, in most areas, by varying the propeller rotational speed.

Some wind tunnel tests on subsonic propellers indicated that satisfactory efficiency can be maintained up to flight speeds of Mach 0.65, at which point efficiency rapidly begins to decrease. With supersonic blades the rapid decrease in efficiency can be prolonged to at least Mach 0.90.

Air Induction Models

Efficiency of the air induction system largely determines the fuel economy and amount of power developed by a turbo-prop engine equipped with a conventional cowling-spinner combination. In the last few years, CAL's propeller dynamometer has been used for experimental research on air induction models. This research has verified many theoretical studies on the effects of the propeller shank and spinner juncture geometry. Significant reductions in total pressure recovery at a cowl inlet and at the engine compressor face have resulted when the propeller shank thickness has been increased. Also, round shank propellers have been found to cause much greater losses than the airfoil shank propeller of the same total thickness.

The relatively small diameter of the nacelle of CAL's dynamometer lends itself well to the exact simulation of a full-scale cowl inlet and engine air duct — extremely necessary if duct losses and recovery pressures are to be evaluated correctly. Hence, in addition to evaluating the aerodynamic performance of an isolated propeller, it is also feasible to conduct propeller tests in the presence of a cowl and to evaluate the ram-air recovery pressures and characteristics of a complete turbo-prop engine installation. A typical installation is shown in Fig. 3.

Several tests of this type have been run in the wind tunnel. Model power plant installations of the Douglas C-124B and C-132 airplanes were successfully installed and tested. The most recent nacelle-propeller tests were those conducted on an installation of the Lockheed-Electra turbo-prop transport. During these tests such problems as ice formation on the propeller blades and spinner were simulated to obtain results on the overall performance of the power plant.

From experiments conducted thus far on the CAL dynamometer, it is readily apparent that much useable data on propeller performance and much basic design information can be and has been obtained. Both the propeller and airframe industries need these kinds of data to assess the arguments of turbo-prop versus turbo-jet for the long range, high-load-carrying aircraft.

ABOUT THE AUTHORS

WILLIAM E. SMITH, author of "Problems in Measurement," since 1955 has been engaged in research and development on a pilot model of the wave superheater — a high temperature device capable of producing a continuous flow of high-speed, high-temperature air for 15 seconds or longer. The wave superheater concept has grown from earlier shock tube research in which Mr. Smith played a leading part at CAL.

He joined the Laboratory in June, 1952 as an Assistant Research Aerodynamicist in the Aerodynamic Research Department. Shortly thereafter, he began studies of the behavior of gases under a wide variety of conditions, participating in theoretical studies and supervising shock tunnel experiments.

Mr. Smith received a B.S. in I. E. from the University of Buffalo in 1950 and an M. Aero. E. from Cornell University in 1952, the latter as a CAL-sponsored fellow. He was a summer student in CAL's Wind Tunnel Department in 1951.

His published papers include a thesis on "Some Examples of Laminar Boundary Layer Flow on Rotating Blades," and reports on high temperature gas dynamics, aerodynamics, and shock tube research. He is a member of the I. A. S.

JOHN P. ANDES, author of "Propellers — A Vanishing Race?", draws upon extensive experience both with a propeller manufacturer — the Propeller Division of Curtiss-Wright — and a research and development laboratory — CAL — to examine the question.

Following a year and a half of service with the U. S. Navy, much of it aboard the USS Midway, he joined Curtiss-Wright in 1946 as a propeller analyst and experimental propeller aerodynamicist, working in conjunction with wind tunnel and flight tests.

He joined CAL in 1952 as a project unit head in the Wind Tunnel, now the Transonic Tunnel Department. He was made head of the Engineering Section in charge of operations in 1954; Head of the Engineering Branch in charge of operations, design, and data reduction in 1956; and Assistant Department Head of the Transonic Tunnel Dept. in 1957. He has been closely connected with both wind tunnel modernization work and installation of high speed computing equipment for data reduction.

He received a B. Aero. E. from R.P.I. in 1945 and took graduate work in Management Engineering at Stevens Institute of Technology in 1951 and 1952.

He is a member of the I.A.S., the American Ordnance Association, and N. Y. State Society of Professional Engineers.

RECENT C. A. L. PUBLICATIONS

The Laboratory invites requests for its unclassified publications as a public service. Supplies of some publications are limited; and those marked with an * may be distributed only within the United States. Please direct your request to the Editor, Research Trends; Cornell Aeronautical Laboratory, Buffalo 21, New York.

"A METHOD FOR EXAMINATION OF STORE SEPARATION FROM AIRCRAFT THROUGH DYNAMIC MODEL TESTING AT FULL SCALE MACH NUMBER," Deitchman, Seymour J.; Reprinted from the Journal of the Aeronautical Sciences, Vol. 24, No. 4; April 1957; 6 pages.

It has been found useful to formulate a set of similarity laws for such testing for the cases most commonly encountered — i.e., freely falling bodies and fin- or spin-stabilized powered projectiles. Consideration has also been given to obtaining model to full-scale similarity of the jet of a powered projectile for study of its effect on the launching aircraft.

"APPLICATION OF THE LEAST SQUARES AVERAGING PROCEDURE TO THE ANALYSIS OF DYNAMIC FLIGHT TEST DATA," Statler, Irving C.; CAL Report FDM No. 268; April 1957; 13 pages.

The least squares averaging procedure provides a valuable method for the determination of the best equation of a specified type to represent observed data. At most, it yields the most probable values for the constants entering an equation of an assumed form, whatever that form may be.

"THEORETICAL AERODYNAMIC FORCES AND MOMENTS FOR A SLENDER BODY MOVING THROUGH THE FLOW FIELD OF A NEARBY SLENDER BODY," Woolard, Henry W.; CAL Report GC-910-C-15; October 1956; 25 pages.

Predictions of these forces and moments is of interest for engine pods, external fuel tanks, and externally mounted bombs and missiles. Applications to the pure translational motion of a body of revolution, and a body of revolution with equal-span cruciform fins are presented.

Melling, William P.; CAL Report UB-1088-P-100; January 1957; 35 pages.

A formulation is provided of the target range required for satisfactory measurement of echoing area in a radar test site. When a conventional antenna is used against a target larger than about 10 wavelengths the necessary range is usually given by PD^2p/λ , where Dp is the maximum projected target model dimension seen by the antenna; λ the test wavelength; and P is a constant (of the order of 3) which effectively defines the quality of measurement.

"ASBESTOS REINFORCED LAMINATES," Wahl, Norman E. and Preston, Harold M.; CAL Report PJ-978-M-15; March 1957; 36 pages.

The use of long-fibered asbestos as a reinforcement for typical polyester, epoxy, silicone and phenolic resins was investigated. Low pressure laminates were prepared and the physical properties were determined.

"A STUDY OF THE NATURE OF ATMOSPHERIC TURBULENCE BASED UPON FLIGHT MEASUREMENT OF THE GUST VELOCITY COMPONENTS," Notess, Charles B.; CAL Report VC-991-F-1; April 1957; 130 pages.*

Power spectral densities of the three orthogonal gust velocity components were obtained by direct calculation from data obtained in flight. Twenty data runs recorded in turbulent air were analyzed to provide information concerning the character of turbulence.

"THE FUTURE CIVIL AIR FLEET," Shatz, Robert H.; Presented at the Tenth Annual Conference of the Airport Operators Council, Chicago; April 1957; 15 pages.

A discussion of the physical and flight characteristics of the civil aircraft that can be expected during the next 20 years, as well as the nature of the common carrier and general aviation fleets that will exist during that period.

"INVESTIGATION OF A VORTEX TUBE ACOUSTIC TRUE AIRSPEED SENSOR," Nicklas, James P.; CAL Report IH-942-P-2; May 1957; 89 pages. *

Investigation has been made of the temperature sensitivity, the altitude sensitivity; and the humidity sensitivity of the vortex tube. Further wind tunnel tests have been conducted and refinements have been made in both the acoustic pick-up system and the aerodynamic design of the vortex tube.

"POLYTROPIC EXPONENTS FOR AIR AT HIGH TEMPERATURES," Logan, Joseph G., Jr. and Treanor, Charles E.; Reprinted from the Journal of the Aeronautical Sciences, Vol. 24, No. 6; 9 pages.

From references cited, it appears possible to relate to each value of the entropy in the real gas region a polytropic exponent from which the relationship between pressure, density, and temperature can be determined.

"THE UNSTEADY LAMINAR BOUNDARY LAYER OF A WEDGE, AND A RELATED THREE DIMENSIONAL PROBLEM," Moore, Franklin K.; Presented at the Heat Transfer and Fluid Mechanics Institute, California Institute of Technology, Los Angeles, California; June 1957; 20 pages.

In order to study the effect of pressure gradient on the unsteady boundary layer, especially one which is near the quasi-steady separation point, a theoretical study is made of Falkner-Skan wedge flow, assuming that the co-efficient of the velocity gradient varies with time. Nearly quasi-steady flow is assumed. Solutions of the disturbance equations are presented for various wedge angles.

"THE SHOCK TUNNEL AND ITS APPLICATIONS TO HYPERSONIC FLIGHT," Hertzberg, Abraham; CAL Report AD-1052-A-5; June 1957; 44 pages. *

This paper discusses the application of the shock tube to the study of problems of hypersonic flight. Modifications of the conventional shock tube which extend the shock tube into a tool for the study of hypersonic flows are described. The problems of operation and technique which these modified shock tubes introduce are discussed. The techniques of instrumentation for the brief flow durations of hypersonic shock tunnels are outlined.

"A FORWARD-SCATTERING OPTICAL DISDROMETER," Hendrick, Roy W., Jr.; CAL Report VD-1030-P; August 1957, 110 pages.*

An airborne instrument for measuring the spectrum of the concentration of droplets of various radii (a disdrometer) was developed. This disdrometer used the quantity of visible light scattered forward at about a 28° angle from its incident direction to measure the radius of individual droplets. Optical and electronic means are used to classify the amplitude of signal pulses from individual droplets so as to produce a cumulative drop size distribution spectrum every two seconds. The present instrument scans the spectrum from 3.5 to 100-micron radius droplets. Means for extending this range down to 2-micron radius are suggested.

"A NEW APPROACH TO THE NON-LINEAR PROBLEMS OF FM CIRCUITS," Biot, M. A.; Reprinted from the Quarterly of Applied Mathematics, Vol. 15, No. 1; April 1957; 10 pages.

Closed form expressions are developed for the output of an FM receiver for an arbitrary number of superposed input signals. This corresponds to problems of interference or disturbance due to scatter and multiple reflexions.